



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Terry L. Gilton and Li Li

Application No. 09/579,345

Filed: May 25, 2000

Confirmation No. 7950

For: SEMICONDUCTOR FABRICATION
METHODS AND APPARATUS

Examiner: George R. Fourson, III

Art Unit: 2823

Attorney Reference No. 6047-55230-01

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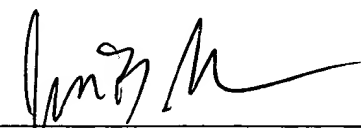
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APPELLANT'S APPEAL BRIEF

This brief is in furtherance of the Notice of Appeal dated May 13, 2004. The fee required under 37 C.F.R. § 1.17(c) is enclosed.

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I. Real Party in Interest

The real party in interest is Micron Technology, Inc., by an assignment from the inventors recorded with the U.S. Patent and Trademark Office at Reel 010017, Frames 0173-0176. Micron Technology, Inc. is a Delaware corporation having a place of business at 8000 S. Federal Way, Boise, Idaho 83706-9632.

II. Related Appeals and Interferences

There are no other appeals or interferences which will directly affect or be directly affected by or have a bearing on the Board's decision in the pending appeal.

III. Status of Claims

Claims 1-5, 10, 17, 20-25, 30, 31, and 38 were previously cancelled and claims 6-9, 11-16, 18, 19, 26-29, and 32-37 are pending in the instant application. Claims 6-9, 11-16, 18, 19, 26-29, and 32-37 are on appeal.

IV. Status of Amendments

All amendments have been entered. Applicants have not filed any amendments subsequent to the final rejection of the application.

V. Summary of Invention

The invention, as set forth in the claims, concerns a method for cleaning or otherwise removing material, such as photoresist, from an in-process semiconductor wafer. FIG. 2 of the present application, for example, shows an apparatus that can be used to practice the method,

according to one embodiment. The apparatus includes a chamber 10 that is sized to receive at least one wafer 12 to be cleaned of photoresist or various other materials or residues. See page 7, lines 20-21 of the application. This embodiment of the apparatus also includes a solvent source 34 (which can be, for example, a boiler) and a reactant-gas source 38, both of which are in communication with the chamber 10. See page 8, lines 1-5.

In use, the solvent source 34 introduces a solvent (e.g., water) into the chamber 10 such that the liquid solvent forms a liquid layer or film on at least one surface of the wafer 12. See page 8, lines 20-21. In certain embodiments, a vaporized solvent is introduced into the chamber and the solvent is condensed to form a film on the wafer surface. To facilitate condensation of the solvent, the wafer may be cooled to a temperature equal to about the dew point of the solvent. See page 9, lines 4-8.

The reactant-gas source 38 introduces into the chamber 10 a reactant gas (e.g., ozone) that is capable of reacting directly with the material that is to be removed from the wafer surface. See page 8, lines 10-13. The liquid solvent layer on the wafer surface serves as a transport medium for the reactant gas by placing the reactant gas in direct physical contact with the wafer surface. The reactant gas is then at a suitable concentration on the wafer surface so as to relatively quickly and effectively react with material on the wafer surface to effect removal of such material. See page 8, lines 19-25.

VI. Issues

A. Whether the Patent Office met its burden of establishing that claims 26, 27, 32, 34, and 37 are anticipated by U.S. Patent No. 6,267,125 to Bergman et al., (Bergman).

B. Whether the Patent Office met its burden of establishing that claims 6-9, 11-16, 18, 19, 28, 29, 33, 35, and 36 are obvious in view of Bergman.

VII. Grouping of Claims

A. Rejection of Claims 26, 27, 32, 34, and 37

Claims 26, 27, 32, 34, and 37 stand rejected as allegedly being anticipated by Bergman. Each of these claims is independently patentable over Bergman. However, to facilitate the Board's consideration of this appeal, Applicants group claims 26, 27, 32, 34, and 37 for this appeal as follows:

The patentability of claim 27 stands or falls with the patentability of claim 26.

The patentability of claim 34 stands or falls with the patentability of claim 32.

The patentability of claim 37 stands or falls on its own.

B. Rejection of Claims 6-9, 11-16, 18, 19, 28, 29, 33, 35, and 36

Claims 6-9, 11-16, 18, 19, 28, 29, 33, 35, and 36 stand rejected as allegedly being obvious in view of Bergman. Independent claims 6, 11, 14, and 16 are independently patentable over Bergman, and their respective dependent claims each contain limitations that further distinguish the claims over Bergman. However, to facilitate the Board's consideration of this appeal, Applicants group claims 6-9, 11-16, 18, 19, 28, 29, 33, 35, and 36 for this appeal as follows:

The patentability of claims 7-9, 16, 18 and 19 stands or falls with the patentability of claim 6.

The patentability of claims 12-15 stands or falls with the patentability of claim 11.

The patentability of claim 28 stands or falls on its own.

The patentability of claim 29 stands or falls on its own.

The patentability of claim 33 stands or falls on its own.

The patentability of claim 35 stands or falls on its own.

The patentability of claim 36 stands or falls on its own.

VIII. Arguments

A. The Cited Prior Art: U.S. Patent No. 6,267,125 to Bergman et al.

Bergman is understood as follows. Bergman discloses an apparatus and method “for supplying a mixture of a treatment liquid and ozone for treatment of a surface of a workpiece, such as a semiconductor workpiece.” See Bergman, col. 2, lines 51-53. FIG. 1 of Bergman shows an apparatus 10 that includes a treatment chamber 15 that contains one or more workpieces 20. See Bergman, col. 4, lines 1-4. One or more nozzles 40 are disposed within the chamber 15 so as to direct a spray mixture of ozone and a treatment liquid onto the surfaces of the workpieces. See Bergman, col. 4, lines 16-19.

FIG. 2 of Bergman shows an apparatus 120 that is similar to apparatus 10 shown in FIG. 1, except that apparatus 120 includes one or more heaters 125 that are used to heat the treatment liquid so that it is supplied to the surfaces of the workpieces at an elevated temperature to accelerate surface reactions. Bergman also teaches directly heating the workpieces to stimulate surface reactions in addition to or instead of indirect heating of the workpieces with the heated treatment liquid. For example, workpiece supports 25 in chamber 15 can include heating elements for directly heating the workpieces and the chamber 15 can include a heater for elevating the temperature of the chamber and workpieces. See Bergman, col. 5, lines 6-25.

FIG. 5 of Bergman shows an apparatus 250 that includes a steam boiler 260 that supplies saturated steam to a treatment chamber 15. Bergman states that this embodiment can achieve workpiece surface temperatures in excess of 100° C, which further accelerates reaction kinetics at the surfaces of the workpieces. See Bergman, col. 6, line 61 through col. 7, line 10.

The Bergman device can also include an ultra-violet lamp 300 positioned in the treatment chamber 15, such as shown in FIG. 6, to irradiate the surface of a workpiece, thereby further enhancing reaction kinetics. See Bergman, col. 7, lines 10-15.

B. 35 U.S.C. § 102(b) Rejection of Claims 26, 27, 32, 34, and 37

Claims 26, 27, 32, 34, and 37 stand rejected under 35 U.S.C. § 102(b) as allegedly being anticipated by Bergman. For at least the following reasons, Applicants disagree that these claims are anticipated by Bergman.

1. Independent Claim 26

Claim 26 is directed to a method of semiconductor fabrication. The method comprises selecting a liquid solvent that is inert to a material on a surface of a wafer, selecting a reactant gas that is capable of chemically reacting with the material on the surface of the wafer and incorporating the reactant gas into the liquid solvent, and showering the liquid solvent incorporating the reactant gas onto the surface of the wafer and exposing the liquid solvent to the reactant gas so that the reactant gas chemically reacts with the material on the surface of the wafer. The method also includes controlling the temperature at or near the surface of the wafer so that the temperature at or near the surface of the wafer is less than the temperature of the showering liquid solvent.

Claim 26 is allowable because Bergman neither teaches nor suggests controlling the temperature at or near the surface of the wafer so that the temperature at or near the surface of the wafer is less than the temperature of the showering liquid solvent, as claimed by Applicants.

In the rejection of claim 26, the Examiner contends that “disclosed examples and preferred embodiments do not constitute a teaching away from a broader disclosure or nonpreferred embodiments.” However, the Examiner does not provide any evidence of any such broader disclosure or nonpreferred embodiments in Bergman that teaches controlling the temperature at or near the surface of the wafer so that the temperature at or near the surface of the wafer is less than the temperature of the showering liquid solvent. In fact, Bergman actually teaches that it would be desirable to heat the surface of a wafer, such as with a heating element or an ultra-violet lamp, to enhance reaction kinetics at the wafer surface. See Bergman, col. 5, lines 19-25 and col. 7, lines 10-14.

The Examiner also cites *Merck & Co., Inc. v. Biocraft Laboratories, Inc.*, 874 F.2d 804, for the proposition that “[a] reference may be relied upon for all that it would have reasonably suggested to one having ordinary skill in the art, including nonpreferred embodiments.” See page 2 of the Office action. However, the Examiner’s reliance on this case is misplaced, since consideration of what a prior art reference would have suggested to one of ordinary skill in the art is only relevant under a section 103(a) inquiry. *Merck*, 874 F.2d at 807. Under 35 U.S.C. § 102(b), a prior art reference anticipates a claim only if each and every element of the claim is found, either expressly or inherently, in the reference. See, e.g., MPEP § 2131 (citing *Verdegaal Bros. v. Union Oil Co. of California*, 814 F.2d 628, 631 (Fed. Cir. 1987)).

That the Examiner improperly rejected the claims under 102(b) is evident in his statement that “it would have been within the scope of one of ordinary skill in the art to employ the recited

temperature range because one of ordinary skill in the art would have had a reasonable expectation of success that with those conditions a film would be maintained on the wafer and that the reaction, although lacking the benefit of enhanced reaction kinetics, would proceed and would therefor have been led to the recited temperature through routine optimization.” See pages 2-3 of the Office action. If “routine optimization” or the knowledge of one skilled in the art would be required to make up for the deficiencies of Bergman, then Bergman necessarily does not teach each and every step recited in claim 26.

For at least the foregoing reasons, the 35 U.S.C. § 102(b) rejection of claim 26 should be reversed.

2. Independent Claim 32

Claim 32 is directed to a method for removing photoresist material from a semiconductor wafer. The method includes selecting a liquid that does not chemically react with photoresist material, cooling the wafer, and forming a layer of the liquid on a surface of the wafer having photoresist material thereon. The method also includes introducing ozone gas over the layer of liquid such that some of the flowing ozone gas is transported through the layer of liquid to the surface of the wafer, and reacting the ozone gas transported to the surface of the wafer with the photoresist material on the wafer surface.

Unlike the method of claim 32, Bergman fails to provide any disclosure that teaches or suggests cooling a wafer. In the 103(a) rejection of claims 6-9, 11-16, 18, 19, 28, 29, 33, 35, and 36 (discussed below), the Examiner even concedes that “Bergman does not disclose cooling the wafer or solvent to the recited temperature or particular recited temperatures.” See page 3 of the

Office action. Since Bergman fails to disclose each and every step recited in claim 32, the 102(b) rejection of claim 32 should be reversed.

3. Independent Claim 37

Claim 37 is directed to a method for removing photoresist material from the surface of the wafer. The method includes vaporizing a mixture of water and ozone gas, condensing a layer of the mixture on a wafer surface having photoresist material thereon, and reacting the ozone gas in the mixture with the photoresist material on the wafer surface to remove the photoresist material therefrom.

Claim 37 is allowable because there is no disclosure in Bergman that teaches or suggests condensing a layer of a water and ozone gas mixture on a wafer surface. In FIGS. 1-4 and 6 of Bergman, Bergman discloses spraying water (in liquid form) through nozzles 40 into a chamber to form a liquid layer on a workpiece. Because the water is not vaporized, it is not later condensed, as recited in claim 37.

Although FIG. 5 of Bergman discloses a steam generator for supplying saturated steam to the process chamber, there is no indication that a liquid layer is formed on the surface of the workpiece. Condensing a vapor can be achieved by either increasing the pressure and/or decreasing the temperature, e.g., cooling the wafer. There is no teaching or suggestion in Bergman to increase the pressure within the chamber or to cool the workpiece so as to form a liquid layer on the surface of the workpiece. Further, as discussed in detail below, Bergman actually teaches away from forming such a layer by specifically teaching *heating* the workpiece.

Accordingly, the rejection of claim 37 should be reversed.

C. 35 U.S.C. § 103(a) Rejection of Claims 6-9, 11-16, 18, 19, 28, 29, 33, 35, and 36

Claims 6-9, 11-16, 18, 19, 28, 29, 33, 35, and 36 stand rejected under 35 U.S.C. § 103(a) as allegedly being obvious from Bergman. For at least the following reasons, Applicants disagree that these claims are obvious from Bergman.

1. Independent Claim 6

Claim 6 is directed a method for semiconductor wafer fabrication. The method includes incorporating a reactant gas that is capable of reacting with a material on the surface of a wafer into a liquid solvent that is inert to the material on the surface of the wafer to provide a reactant mixture, forming a film of the reactant mixture on the surface of the wafer so that the reactant gas is transported through the film of reactant mixture to the surface of the wafer and reacts with the material thereon, and cooling the wafer to a temperature equal to or less than about a dew point of the liquid solvent in the reactant mixture to facilitate the formation of the film of the reactant mixture on the surface of the wafer.

Claim 6 is allowable over Bergman because this reference neither teaches nor suggests cooling a wafer to a temperature equal to or less than about a dew point of a liquid solvent in a reactant mixture to facilitate the formation of a film of the reactant mixture on the surface of the wafer.

To establish a *prima facie* case of obviousness, there must be some suggestion or motivation, either in the references or in the knowledge generally available to one of ordinary skill in the art, to modify a reference or to combine reference teachings. MPEP § 2143.

However, there is no suggestion to combine or modify if a reference teaches away from making the specific combination of elements recited in a claim. *See Tec Air, Inc. v. Denso Mfg. Mich.*

Inc., 192 F.3d 1353, 1360, 52 U.S.P.Q. 2d 1294, 1298 (Fed. Cir. 1999); *In re Fine*, 837 F. 2d 1071 (Fed. Cir. 1988) (holding that the prior art contained no teaching or suggestion to substitute a nitric oxide detector of the secondary reference with the sulfur dioxide detector of the primary reference because the latter taught against detecting for the presence of nitrogen compounds). “A reference may be said to teach away when a person of ordinary skill, upon reading the reference, would be . . . led in a direction divergent from the path that was taken by the Applicant” *Tec Air*, 192 F.3d at 1360. *See also In re Arbeit et al.*, 201 F.2d 923, 96 USPQ 397 (C.C.P.A. 1953) (finding the applicants’ argument convincing that certain claims were patentable because the primary emphasis of the prior art reference was “diametrically opposed” to the applicant’s invention).

Also, proceeding contrary to the accepted wisdom of the prior art is strong evidence of non-obviousness. *See In re Hedges*, 783 F.2d 1038, 1041 (Fed. Cir. 1986). In *Hedges*, the Court reversed the PTO’s rejection of a claim directed to sulfonating diphenyl sulfone at a temperature above 127 °C. The Court held that the PTO did not carry its burden of proving non-obviousness because the claim was contrary to the accepted wisdom of the prior art as a whole, which suggested using lower temperatures for optimum results. *Id.*

In the present case, Bergman teaches away from cooling a wafer to a temperature equal to or less than about a dew point of a liquid solvent, as claimed by Applicants, in that the primary emphasis of Bergman concerns *heating* the workpiece to an elevated temperature to accelerate reaction kinetics at the surface of the workpiece. For example, Bergman states that in “a preferred method for treating a workpiece, the workpiece is first heated.” (emphasis added) See Bergman, col. 3, lines 13-14.

In another passage, referring to the system 120 shown in FIG. 2, Bergman states the following:

The system 120 of FIG. 2 is based upon the recognition by the present inventors that the heating of the surfaces of the semiconductor workpieces 20 with a heated liquid that is supplied along with a flow of ozone that creates a ozonated atmosphere is highly effective in photoresist stripping, ash removal, and/or cleaning processes. As such, system 120 includes one or more heaters 125 that are used to heat the treatment liquid so that it is supplied to the surfaces of the semiconductor workpieces at an elevated temperature that accelerates the surface reactions. It will be recognized that it is also possible to directly heat the workpieces so as to stimulate the reactions. Such heating may take place in addition to or instead of the indirect heating of the workpieces through contact with the heated treatment liquid. For example, supports 25 may include heating elements that may be used to heat the workpieces 20. The chamber may include a heater for elevating the temperature of the chamber environment and workpieces.

(emphasis added) See Bergman, col. 5, lines 8-25.

FIG. 6 of Bergman illustrates an embodiment that includes an ultra-violet lamp 300 for irradiating the surface of the semiconductor workpiece 20 during processing. Bergman explains that “[s]uch irradiation further enhances the reaction [kinetics].” See Bergman, col. 7, lines 10-15.

These passages of Bergman unequivocally advocate the importance of enhancing reaction kinetics during processing through heating a workpiece and that optimum results are achieved at elevated surface temperatures. Not only does Bergman fail to teach or suggest cooling a wafer, Bergman’s teachings are diametrically opposed to the method recited in claim 6. As such, claim 6 clearly would not have been obvious to one of ordinary skill in the art in view of Bergman.

The Examiner’s findings in the Office action reinforce that Bergman fails to provide any motivation or teachings that would lead one skilled in the art to modify the Bergman method. In particular, the Examiner states that “[t]he temperature ‘path’ taken to get to the temperature of the combination, like the physical path taken by the reactants, would not be expected to have a bearing on the process of the combinations.” (emphasis added) See page 3 of the Office action.

If one skilled in the art, having knowledge of Bergman, would not have expected that cooling a wafer would affect the process, then the reference teachings necessarily do not provide any motivation to modify the Bergman method. In the absence of any such motivation in the prior art to modify Bergman, claim 6 is not rendered obvious by this reference.

The Examiner also contends that “the recited temperature path and temperatures would have been expected to be operable in the process of the combination and would have been arrived at through routine experimentation.” On the contrary, as noted above, Bergman emphasizes throughout his specification the need to heat and maintain a semiconductor wafer at an elevated temperature during processing. There is nothing in Bergman that suggests that his method would benefit from cooling the wafer. Thus, one skilled in the art seeking to improve or optimize the Bergman method would not have motivated to cool a wafer in the manner recited in claim 6. If anything, based on the teachings of Bergman, one skilled in the art might expect that cooling a wafer would hinder or possibly prevent the removal of material from the wafer surface due to a decrease in the kinetic reaction rate.

Further, the Examiner’s conclusion that Applicants’ method “would have been arrived at through routine experimentation” is contrary to the teachings of Bergman, and could only have been made using hindsight knowledge of Applicants’ method. *See Hedges*, 783 F.2d at 1040 (disagreeing with the PTO position that determining the optimum temperature recited in a claim is a matter of “routine experimentation” where a claim covered sulfonating diphenyl sulfone at a temperature above 127 °C and the prior art suggested using lower temperatures for optimum results). When an examiner is modifying a reference to reject a claimed invention as being obvious under § 103(a), he must be guided by the prior art and not that which is disclosed by the inventor. *See In re Dembiczak*, 175 F.3d 994, 998-99 (Fed. Cir. 1999). Consequently, the

Federal Circuit has rigorously applied the requirement for a showing of a teaching, suggestion, or motivation to combine or modify prior art references to prevent hindsight-based obviousness analyses under § 103(a). *See, e.g., In re Dembiczak*, 175 F.3d at 999; *W.L. Gore & Assoc., Inc., v. Garlock, Inc.*, 721 F.2d 1540, 1553 (Fed. Cir. 1983); and *In re Oetiker*, 977 F.2d 1443, 1447 (Fed. Cir. 1992). In the present case, the Examiner, using hindsight, concluded that Applicants' method would have been obvious in view Bergman, without providing any suggestions or incentives from the prior art that would have motivated one skilled in the art to practice Applicants' method.

Accordingly, for at least the foregoing reasons, claim 6 is not anticipated or rendered obvious by Bergman, and the rejection of claim 6 should be reversed.

2. Independent Claim 11

Claim 11 is allowable because there is no disclosure in Bergman that teaches or suggests condensing a liquid solvent onto a surface of a wafer, as recited in claim 11. In FIGS. 1-4 and 6 of Bergman, Bergman discloses spraying water (in liquid form) through nozzles 40 into a chamber to form a liquid layer on a workpiece. Because the water is not vaporized, it is not later condensed, as recited in claim 11.

With regard to the embodiment shown in FIG. 5 of Bergman, which includes a steam generator for supplying saturated steam to the process chamber, there is no indication that a liquid layer is formed on the surface of the workpiece in the chamber. Condensing a vapor can be achieved by either increasing the pressure and/or decreasing the temperature, e.g., cooling the wafer. There is no teaching or suggestion in Bergman to increase the pressure within the chamber or to cool the workpiece so as to form a liquid layer on the surface of the workpiece.

Further, as noted above, Bergman actually teaches away from forming such a layer by specifically teaching *heating* the workpiece.

Accordingly, the rejection of claim 11 should be reversed.

3. Dependent Claims 28 and 29

Claims 28 and 29 depend from independent claim 26 and therefore are allowable along with claim 26. In addition, claims 28 and 29 set forth respective combination of features that are independently patentable.

For example, claim 28 recites that the wafer is at a temperature equal to about 25 °C and the liquid solvent is at a temperature equal to about 90 °C. In contrast, Bergman emphasizes the need to maintain the surfaces of workpieces at an elevated temperature to accelerate surface reactions. With respect to the embodiment shown in FIG. 5 of Bergman, Bergman states that this embodiment can “achieve semiconductor workpiece surface temperatures in excess of 100 degrees Celsius, thereby further accelerating the reaction kinetics.” Col. 7, lines 5-10. The specific wafer temperature recited in claim 28 is significantly different than the surface temperatures contemplated by Bergman for his process.

Claim 29 recites supporting a wafer in vertical position relative to a shower of liquid solvent. In contrast, in all of embodiments disclosed in Bergman, wafers are supported in a horizontal position. Further, there is no disclosure in Bergman that suggests the desirability of supporting wafers in a vertical position.

For at least the foregoing reasons, the rejections of claims 28 and 29 should be reversed.

4. Dependent Claims 33, 35, and 36

Claims 33, 35, and 36 depend from independent claim 32. As discussed above, Bergman fails to teach or suggest cooling a wafer, as recited in claim 32. Thus, claims 33, 35, and 36 also would not have been obvious from Bergman and the rejection of these claims should be reversed.

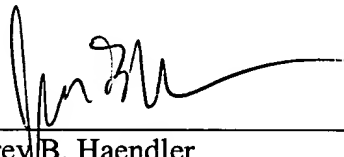
IX. Conclusion

The Final Rejection failed to establish anticipation of claims 26, 27, 32, 34, and 37 or obviousness of claims 6-9, 11-16, 18, 19, 28, 29, 33, 35, and 36. Accordingly, the rejection of these claims should be reversed and all claims passed to issue.

Respectfully submitted,

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APPENDIX

CLAIMS ON APPEAL

6. A method for semiconductor wafer fabrication, the method comprising:

incorporating a reactant gas that is capable of reacting with a material on the surface of a wafer into a liquid solvent that is inert to the material on the surface of the wafer to provide a reactant mixture;

forming a film of the reactant mixture on the surface of the wafer so that the reactant gas is transported through the film of reactant mixture to the surface of the wafer and reacts with the material thereon; and

cooling the wafer to a temperature equal to or less than about a dew point of the liquid solvent in the reactant mixture to facilitate the formation of the film of the reactant mixture on the surface of the wafer.
7. The method of claim 6, wherein the reactant gas is inert with respect to the liquid solvent.
8. The method of claim 6, wherein the thin film of the reactant mixture has a thickness of from about 1 micron to about 100 microns.
9. The method of claim 6, further including flowing the reactant gas over the thin film of the reactant mixture such that some of the flowing reactant gas is transported through the film to the surface of the wafer.

11. A method for removing a material from a surface of a semiconductor wafer, the method comprising:

selecting a reactant gas capable of reacting with a material on a wafer surface;
condensing a liquid solvent onto a surface of the wafer from which material is to be removed, the liquid solvent being inert to the material on the wafer surface; and
exposing the condensed liquid solvent to the reactant gas, the reactant gas being inert to the solvent and reacting with the material on the wafer surface to remove such material.

12. The method of claim 11, further including incorporating reactant gas into the liquid solvent to form a liquid solvent that comprises a reactant mixture that contains reactant gas, and wherein the step of condensing the liquid solvent comprises condensing the reactant mixture on a surface of the wafer such that the reactant gas reacts with and removes the material on the wafer surface.

13. The method of claim 11, further including removing the reactant mixture from the wafer surface.

14. A method for semiconductor wafer fabrication, the method comprising:
vaporizing a liquid solvent that is inert to a material on a surface of a wafer;
selecting a reactant gas that is capable of chemically reacting with the material on the surface of the wafer;
incorporating the reactant gas into the vaporized liquid solvent; and

condensing the vaporized solvent incorporating the reactant gas to form a film on the surface of the wafer so that the reactant gas is transported through the film to the material on the surface of the wafer.

15. The method of claim 14, further including flowing the reactant gas over the film such that some of the flowing reactant gas is transported through the film to the surface of the wafer and cooling the vaporized liquid solvent to facilitate condensation of the vaporized liquid solvent on the surface of the wafer.

16. A method for semiconductor wafer fabrication, the method comprising:
selecting a liquid solvent that is inert to a material on a surface of a wafer;
forming a mist of liquid solvent droplets above the surface of the wafer;
selecting a reactant gas that is capable of chemically reacting with the material on the surface of the wafer and exposing the reactant gas to the liquid solvent droplets;
forming, on the surface of the wafer, a film of the liquid solvent and exposing the film to the reactant gas so that the reactant gas is transported through the film to the material on the surface of the wafer; and
cooling the wafer to a temperature equal to or less than about a dew point of the liquid solvent.

18. The method of claim 16, wherein only one reactant gas is used.

19. The method of claim 16, wherein the film has a thickness of from about 1 micron to about 100 microns.

26. A method of semiconductor fabrication, the method comprising:
selecting a liquid solvent that is inert to a material on a surface of a wafer;
selecting a reactant gas that is capable of chemically reacting with the material on the surface of the wafer and incorporating the reactant gas into the liquid solvent;
showering the liquid solvent incorporating the reactant gas onto the surface of the wafer and exposing the liquid solvent to the reactant gas so that the reactant gas chemically reacts with the material on the surface of the wafer; and
controlling the temperature at or near the surface of the wafer so that the temperature at or near the surface of the wafer is less than the temperature of the showering liquid solvent.

27. A method according to claim 26, wherein the exposing step comprises exposing a film of the liquid solvent to the reactant gas while the film is on the wafer surface.

28. The method of claim 26, wherein the wafer is at a temperature equal to about 25 °C and the liquid solvent is at a temperature equal to about 90 °C.

29. The method of claim 26, wherein the wafer is supported in a vertical position relative to the shower of liquid solvent.

32. A method for removing photoresist material from a semiconductor wafer, the method comprising:

selecting a liquid that does not chemically react with photoresist material;

cooling the wafer;

forming a layer of the liquid on a surface of the wafer having photoresist material thereon;

introducing ozone gas over the layer of liquid such that some of the flowing ozone gas is transported through the layer of liquid to the surface of the wafer; and

reacting the ozone gas transported to the surface of the wafer with the photoresist material on the wafer surface.

33. The method of claim 32, wherein the ozone gas is introduced prior to the formation of the layer of liquid.

34. The method of claim 32, wherein the ozone gas is introduced simultaneously with the formation of the layer of liquid.

35. The method of claim 32, wherein the ozone gas is introduced after the formation of the liquid layer.

36. The method of claim 32 in which the liquid layer is less than about 100 microns thick over the majority of the wafer surface containing the liquid layer.

37. A method for removing photoresist material from the surface of the wafer, the method comprising:

- vaporizing a mixture of water and ozone gas;
- condensing a layer of the mixture on a wafer surface having photoresist material thereon;
- and
- reacting the ozone gas in the mixture with the photoresist material on the wafer surface to remove the photoresist material therefrom.